

IN THE CLAIMS:

- 1 1. (CANCELLED)
- 2 2. (CURRENTLY AMENDED) A method of automatically calibrating a water distribu-
3 tion model of a water distribution network, comprising the steps of:
- 4 (A) selecting calibration parameters to be adjusted to calibrate the water distri-
5 bution model, the calibration parameters including link status and one or
6 more of, pipe roughness and junction demand;
- 7 (B) collecting field observed data including a pipe flow measurement and a
8 junction pressure measurement for at least one point in the water distribu-
9 tion network, and including corresponding loading conditions and bound-
10 ary conditions describing settings of valves or pumps that existed in the
11 network when said field observed data was collected and passing such in-
12 formation to a genetic algorithm module;
- 13 (C) generating at said genetic algorithm module a population of calibration so-
14 lutions that comprise a set of calibration results, using a genetic algorithm;
- 15 (D) running multiple hydraulic simulations of each solution to obtain a set of
16 predictions of pipe flows and junction pressures at selected points in the
17 network, corresponding to the loading conditions and associated boundary
18 conditions when the field observed data was collected;
- 19 (E) performing a calibration evaluation including: —computing a good-
20 ness-of-fit value for each calibration solution based upon differences be-
21 tween field observed values and said predictions;
- 22 (F) repeating steps (C) through (E) until a user-selected desired goodness-of-
23 fit value is obtained resulting in a corresponding calibration solution for
24 calibrating a water distribution model; and
- 25 (G) building a calibrated water distribution model using the desired set of cali-
bration parameters providing the corresponding calibration solution.
- 1 3. (CURRENTLY AMENDED) The method of automatically calibrating a water distri-
2 bution model as defined in claim 2, including the further steps of:

- 3 (A) prior to passing said field observed data to said genetic algorithm module,
4 selecting a weighting function for at least one of said field observed data
5 measurements, said weighting function formulated as a weighting factor of
6 observed pressure heads and flows;
- 7 ~~(B) selecting as said weighting factor one of a linear, square, square-root or~~
8 ~~log function of the ratio of individual value for flow or hydraulic pressure~~
9 ~~to a sum of the observed values of flows or hydraulic pressures; and~~
- 10 (CB) applying said weighting function to said field observed data when running
11 said calibration evaluation to determine said goodness-of-fit value.

1 4. (PREVIOUSLY PRESENTED) The method of automatically calibrating a water dis-
2 tribution model, as defined in claim 2, including the further step of:

3 selecting as said loading condition, at least one water demand loading at a prede-
4 termined time of day, corresponding to a time of day when a field observed data meas-
5 urement has been made.

1 5. (ORIGINAL) The method of automatically calibrating a water distribution model, as
2 defined in claim 4, including the further step of selecting multiple loading conditions rep-
3 resenting demand loading at various times of day when field observed data measurements
4 have been made.

1 6. (PREVIOUSLY PRESENTED) The method of automatically calibrating a water dis-
2 tribution model as defined in claim 2 wherein said boundary conditions include water
3 storage tank levels, pressure control valve settings and pump operation speeds.

1 7. (PREVIOUSLY PRESENTED) The method of automatically calibrating a water dis-
2 tribution model as defined in claim 2 including the further step of:

3 after said desired goodness-of-fit value and corresponding calibration solution is
4 obtained, making manual adjustments to this information for said water distribution
5 model calibration.

1 8. (PREVIOUSLY PRESENTED) The method of automatically calibrating a water dis-
2 tribution network model as defined in claim 2, including the further step of performing a
3 sensitivity analysis by varying model input parameters over a predetermined range and
4 observing the response thereto of said model.

1 9. (ORIGINAL) The method of automatically calibrating a water distribution network
2 model as defined in claim 8 including the further step of adjusting the collection of field
3 observed samples based upon the results of said sensitivity analysis.

1 10. (CURRENTLY AMENDED) A computer readable medium containing executable
2 program instructions for automatically calibrating a water distribution model of a water
3 distribution network that has links that include pipes and junctions, the executable pro-
4 gram instructions comprising program instructions for:

5 (A) ~~generating~~ a graphic user interface by which a user may enter data con-
6 cerning field observed data, demand alternatives and other information for
7 the network;

8 (B) a calibration module configured to ~~produce calibration information for a~~
9 ~~water distribution model constructed from~~ adjust user-selected calibration
10 parameters to calibrate the water distribution model, the calibration pa-
11 rameters including link status and one or more of, pipe roughness and
12 junction demand ~~that include at least one of pipe roughness, junction de-~~
13 ~~mand information, roughness groups, and link status;~~

14 (C) a genetic algorithm module coupled to said calibration module and said
15 user interface that receives information about said calibration parameters,
16 and user-entered field observed data, including field data that include cali-
17 bration target data and boundary data describing settings of valves or
18 pumps, said genetic algorithm being configured to produce a population of
19 calibration solutions, and said graphic user interface further being config-

20 ured to allow the user to select at least one of goodness-of-fit criteria, a
21 weighting function, and one or more genetic algorithm parameters; and
22 (D) a hydraulic network simulation module communicating with said genetic
23 algorithm module such that calibration solutions generated by said genetic
24 algorithm module can be run by said hydraulic network simulation module
25 to predict actual behavior of said network, such that predictions are passed
26 back to said calibration module for comparison with field observed data to
27 produce goodness-of-fit values, until a desired goodness-of-fit value satis-
28 fying user-selected goodness-of-fit criteria is obtained resulting in a corre-
29 sponding calibration solution for calibrating a water distribution model;
30 wherein the corresponding calibration solution is used to build a calibrated water
31 distribution model~~provided for use.~~

1 11. (CANCELLED)

1 12. (CURRENTLY AMENDED) The computer readable medium as defined in claim 10,
2 ~~comprising program instructions for performing the further steps of—wherein the genetic~~
3 ~~algorithm module is configured to repetitively compute ing~~-successive generations of so-
4 lutions in one or more calibration runs, and calibration solutions are stored for retrieval
5 and evaluation.

1 13. (CURRENTLY AMENDED) The computer readable medium as defined in claim 10
2 further comprising program instructions for:
3 a database including information regarding water distribution networks for con-
4 structing models of said networks, and into which information can be saved.

1 14. (CURRENTLY AMENDED) The computer readable medium as defined in claim 10
2 wherein said graphic user interface further allows the user to enter information regarding

3 alternative demand loadings, representing a demand for water supply at a given point in
4 time, at a given location in the network.

1 15. (CURRENTLY AMENDED) ~~A~~The method as described in claim 2 wherein link
2 status is a status of being opened or closed of one or more of pipes, or valves and; as be-
3 ing on or off for pumps, in the water distribution model of the water distribution network
4 that is being calibrated.

1 16. (PREVIOUSLY PRESENTED) The method as defined in claim 2 further comprising
2 the step of:
3 computing a roughness value, roughness multiplier, and identifying link status.

1 17. (CANCELLED)

1 18. (PREVIOUSLY PRESENTED) The computer readable medium as defined in claim
2 10 comprising program instructions for performing the further steps of:
3
4 pausing a calibration run;
5 determining intermediate values;
6 observing the intermediate values by a user and
7 resuming said calibration run.

1 19-22. (CANCELLED)

1 23. (CURRENTLY AMENDED) A computer implemented method, the method compris-
2 ing:
3 calibrating a water distribution model wherein model calibration parameters are
4 generated by providing an initial selection of parameters to be ~~determined~~ adjusted in-

cluding link status and one or more of pipe roughness and junction demand to a genetic algorithm module, and performing the steps of:

- (A) receiving at said genetic algorithm module, said selected parameters and field observed data, and generating at said genetic algorithm module a calibration solution for said calibration parameters;
- (B) receiving said calibration solution at an associated hydraulic simulation module and running a hydraulic simulation of the model using said calibration solution;
- (C) producing as a result at said hydraulic simulation module, a set of predictions of junction pressures and pipe flows for nodes in a water distribution model for said calibration solution;
- (D) passing said predictions for that calibration solution to an associated calibration module to evaluate how closely the predictions are to field observed data and assigning a goodness of fit value to that calibration solution;
- (E) repeating steps A through D a plurality of times and passing the goodness of fit value to a genetic algorithm module for each solution;
- (F) calculating at said genetic algorithm module, solutions that correspond with a minimum discrepancy between the simulated predictions and the observed data to obtain a desired set of calibration parameters for use in calibrating a water distribution model; and

building a calibrated water distribution model using the desired set of calibration parameters
~~providing the desired set of calibration parameters.~~

24. (PREVIOUSLY PRESENTED) The method as defined in claim 23 including the further step of performing a sensitivity analysis by varying parameters for a roughness, de-

3 mand and link status over a predetermined range and observing the relative change in the
4 model response thereto.

1 25. (PREVIOUSLY PRESENTED) The method as defined in claim 23 including the fur-
2 ther step of matching the model to historical field conditions.

1 26. (PREVIOUSLY PRESENTED) The method as defined in claim 23 including the fur-
2 ther step of assigning a selected group of pipes to be in a particular roughness group and
3 assigning a roughness calibration variable being one of a roughness coefficient or a
4 roughness coefficient multiplier as the roughness calibration parameter for that roughness
5 group.

1 27. (CANCELLED)

1 28. (PREVIOUSLY PRESENTED) The method of automatically calibrating a water
2 distribution network model as defined in claim 2 wherein link status indicates whether
3 valves, pipes or pumps are open or closed.

1 29. (CURRENTLY AMENDED) A computer implemented method, the method com-
2 prising:

3 calibrating a water distribution model wherein a plurality of model calibration pa-
4 rameters are generated by providing an initial selection of parameters to be adjusted de-
5 termined to a genetic algorithm module, the initial selection of parameters including both
6 pipe and valve operational state and junction demand, and performing steps of:

7 (A) receiving at said genetic algorithm module, said selected parame-
8 ters and field observed data, and generating at said genetic algo-
9 rithm module a calibration solution for said calibration parameters;

- 10 (B) receiving said calibration solution at an associated hydraulic simu-
11 lation module and running a hydraulic simulation of the model us-
12 ing said calibration solution;
- 13 (C) producing as a result at said hydraulic simulation module, a set of
14 predictions of junction pressures and pipe flows for nodes in a wa-
15 ter distribution model for said calibration solution;
- 16 (D) passing said predictions for that calibration solution to an associ-
17 ated calibration module to evaluate how closely the predictions are
18 to field observed data and assigning a goodness of fit value to that
19 calibration solution;
- 20 (E) repeating steps A through D a plurality of times and passing the
21 goodness of fit value to a genetic algorithm module for each solu-
22 tion;
- 23 (F) calculating at said genetic algorithm module, solutions that corre-
24 spond with a minimum discrepancy between the simulated predic-
25 tions and the observed data to obtain a desired set of calibration pa-
26 rameters for use in calibrating a water distribution model; and
- 27 building a calibrated water distribution model using the desired set of calibration
28 parameters.